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(54) **ELECTROPOLISHING FIXTURE WITH LEVER ARM**


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***C25F 3/16*** (2006.01)

(52) **U.S. Cl.**
CPC .... ***C25F 3/16*** (2013.01); ***C25F 7/00*** (2013.01)

(58) **Field of Classification Search**
CPC ............................ C25F 3/16–3/28; C25F 7/00
See application file for complete search history.


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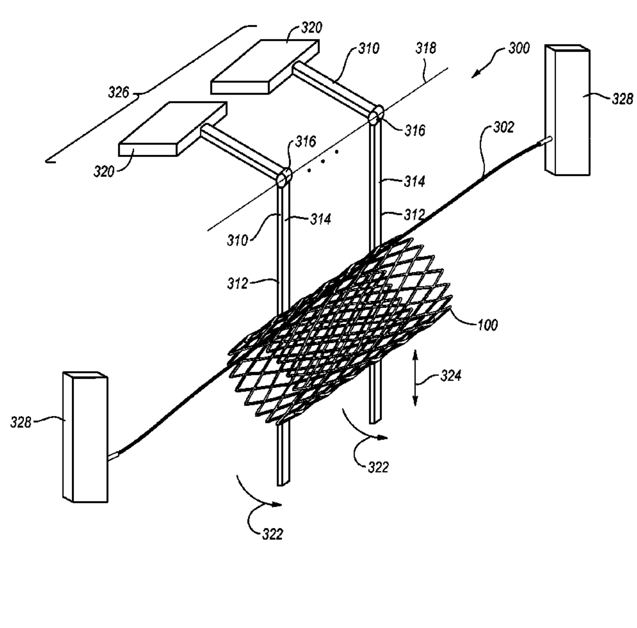
(57) **ABSTRACT**


An electropolishing system that includes electropolishing fixtures. The electropolishing fixtures include pendulum assemblies configured to establish electrical contact between a device being electropolished and an anode and to reposition the device during the electropolishing process.


**19 Claims, 12 Drawing Sheets**



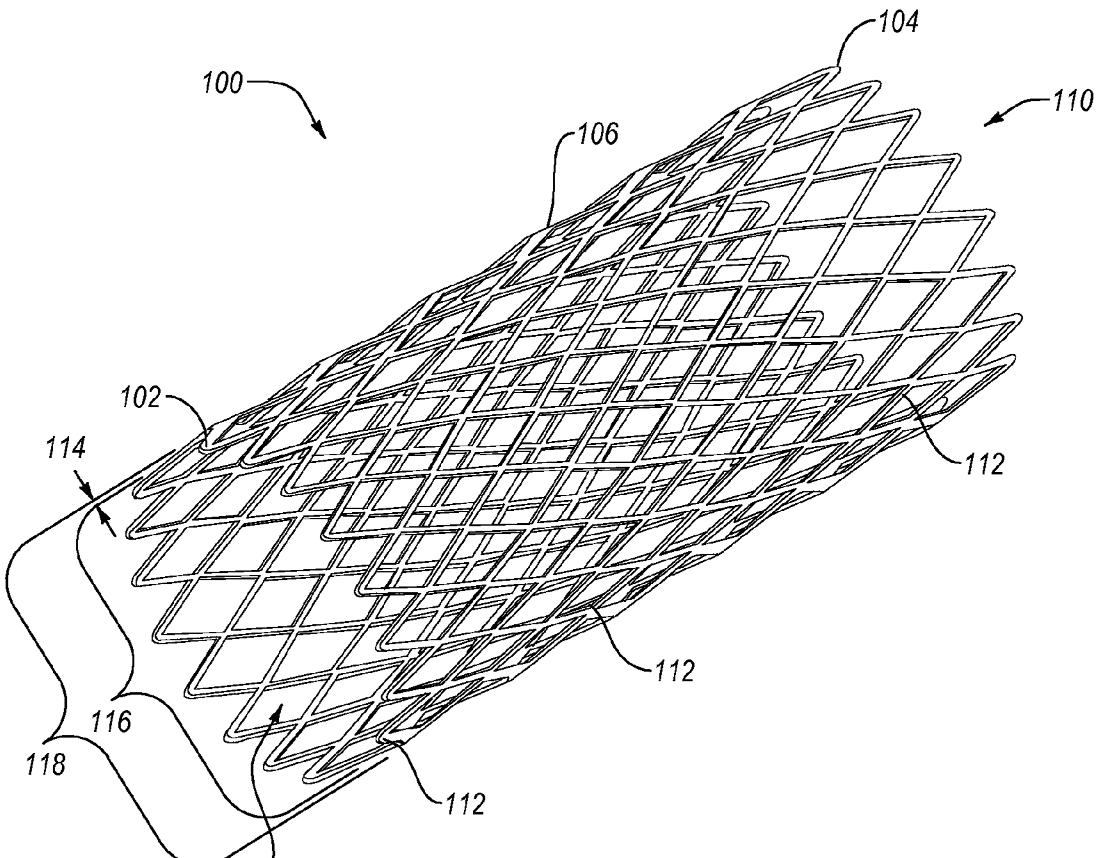
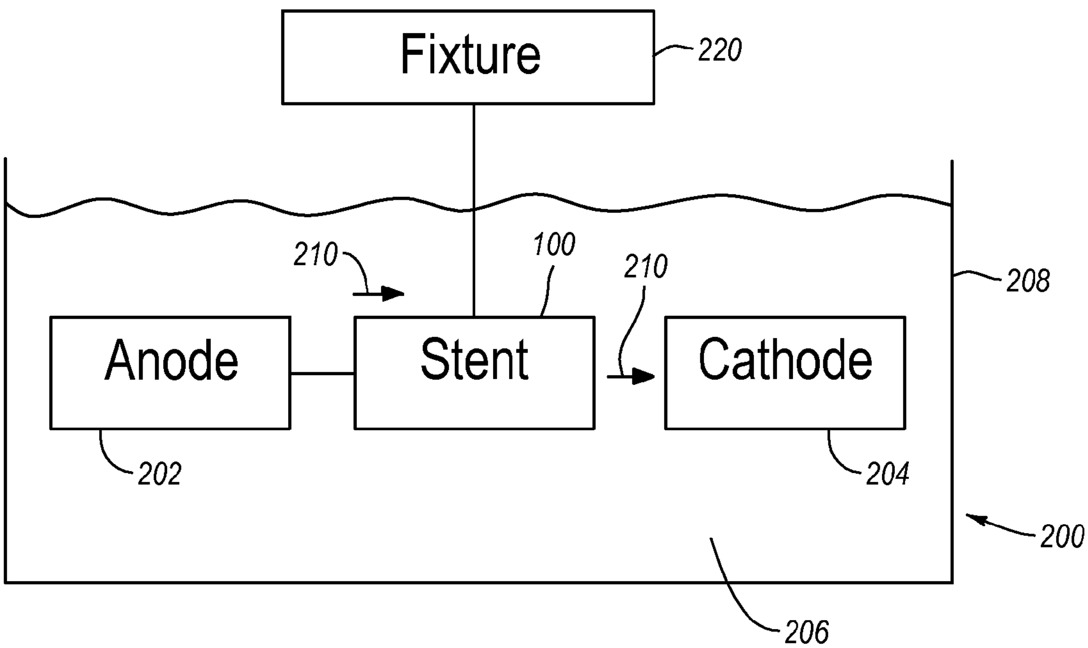



Fig. 1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208
Anode
Stent
Cathode
202
204
200
206

Fig. 2

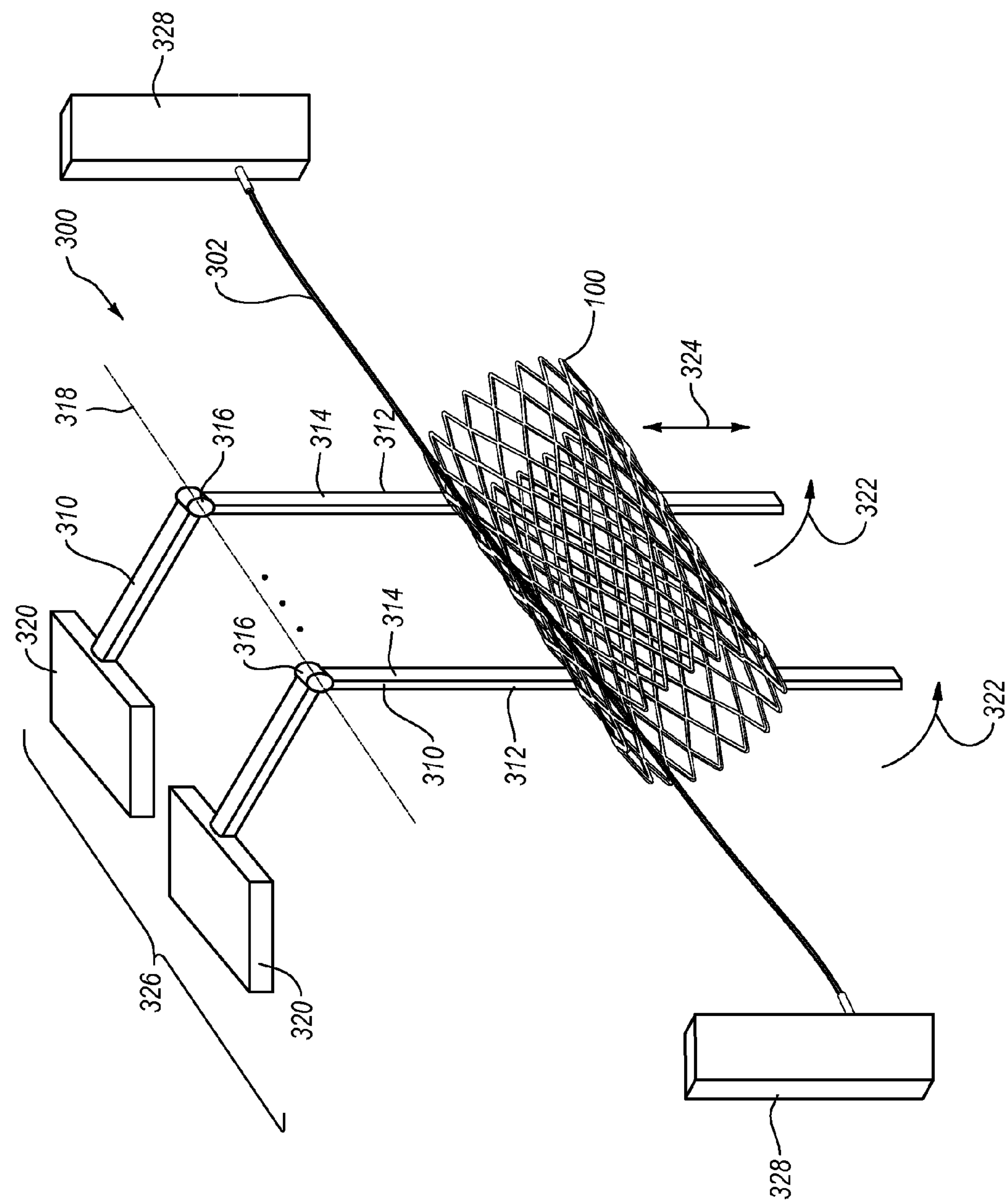
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Fig. 3

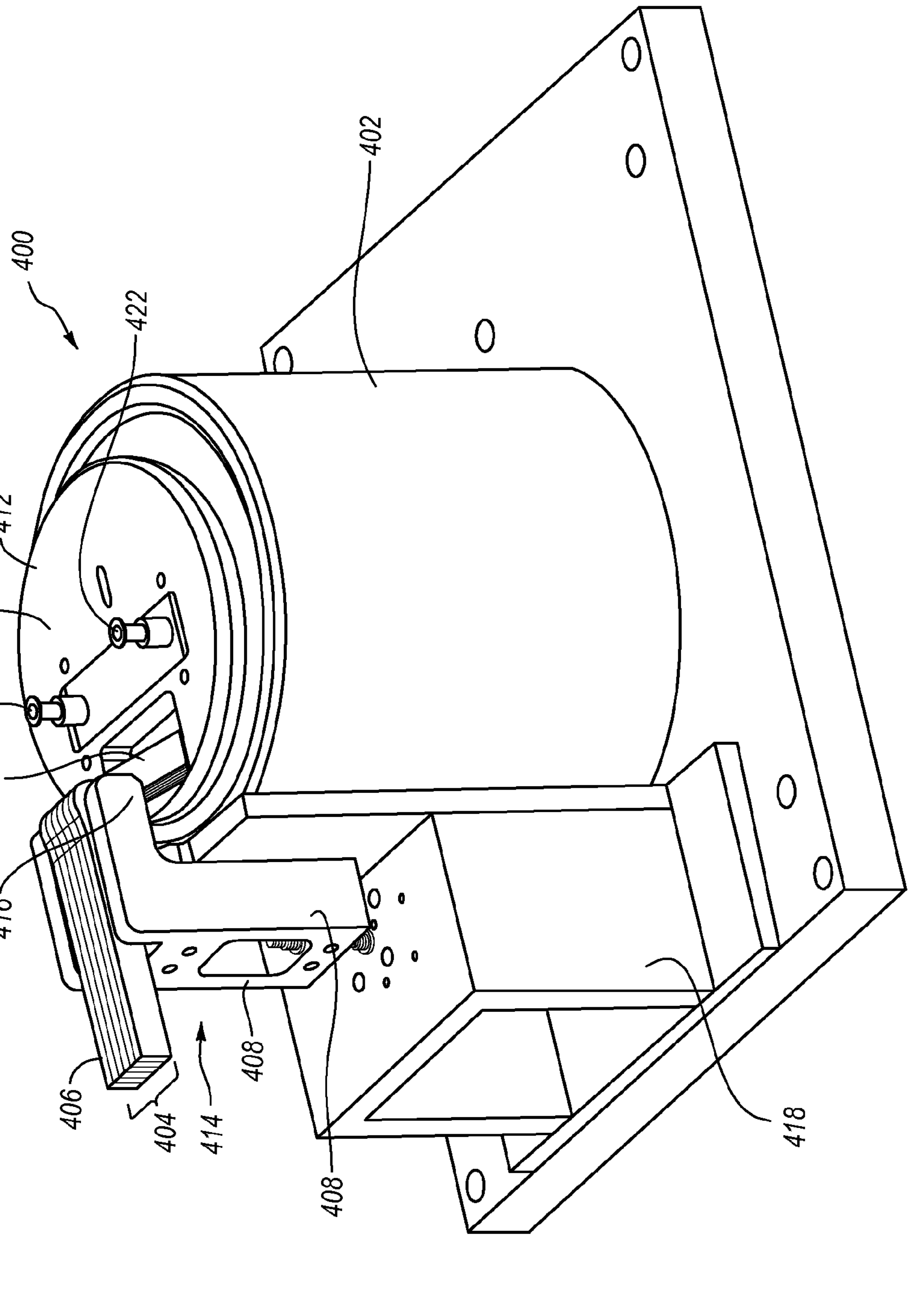


Fig. 4

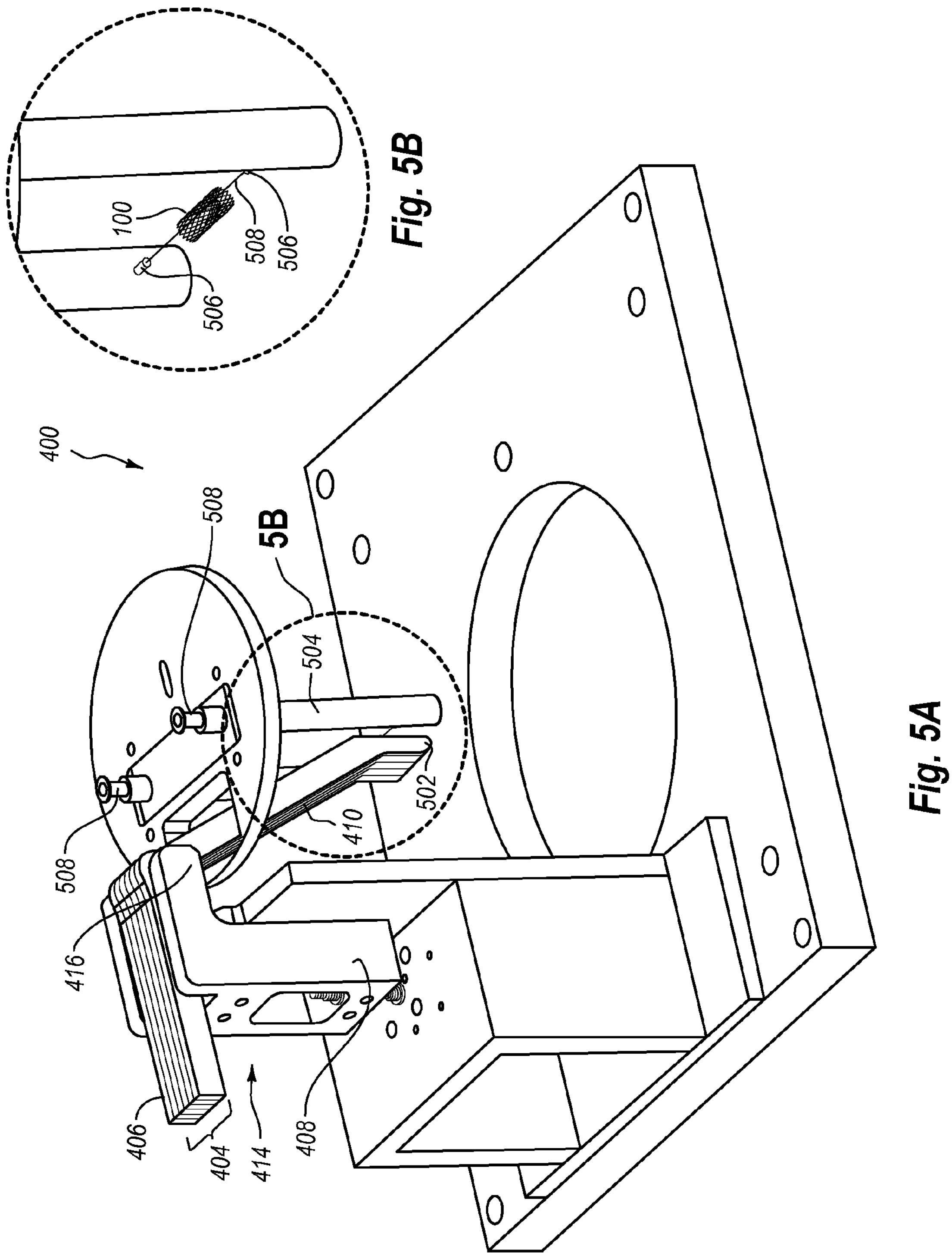


Fig. 5B

Fig. 5A

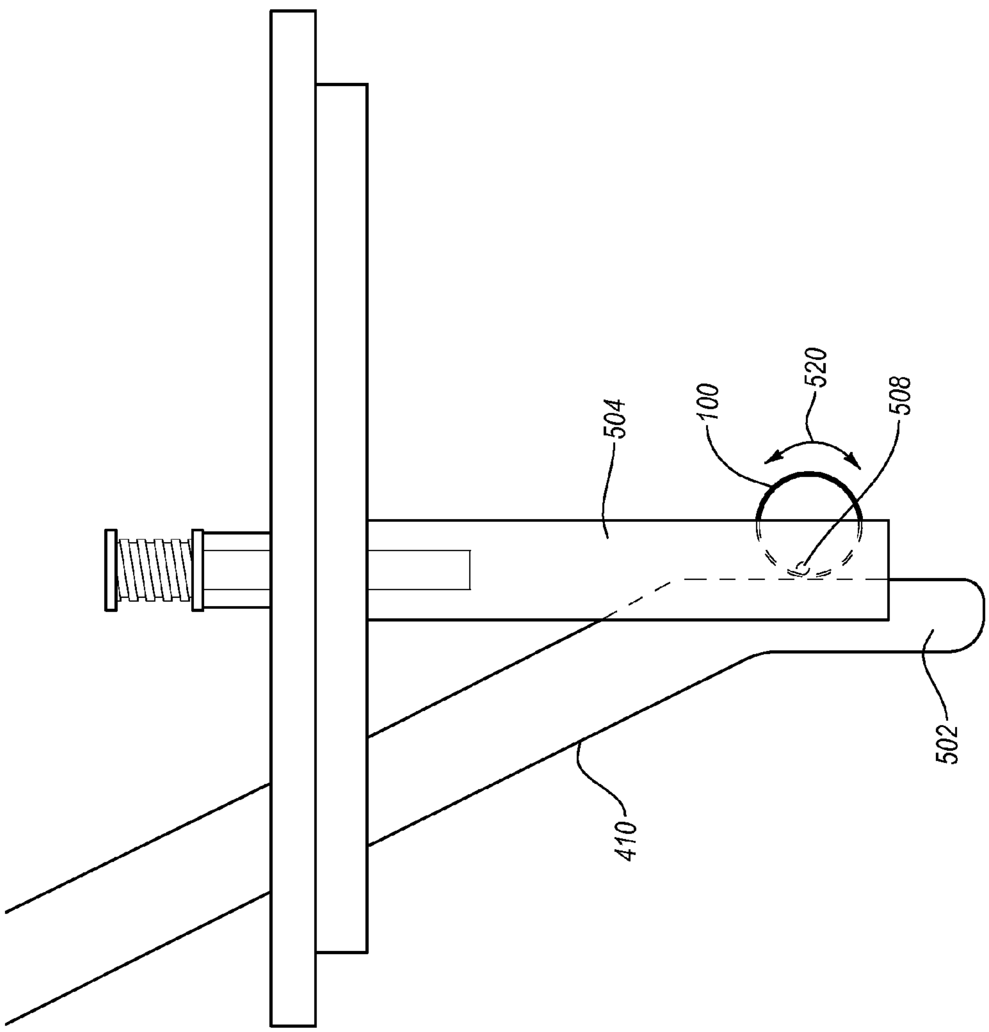


Fig. 5C

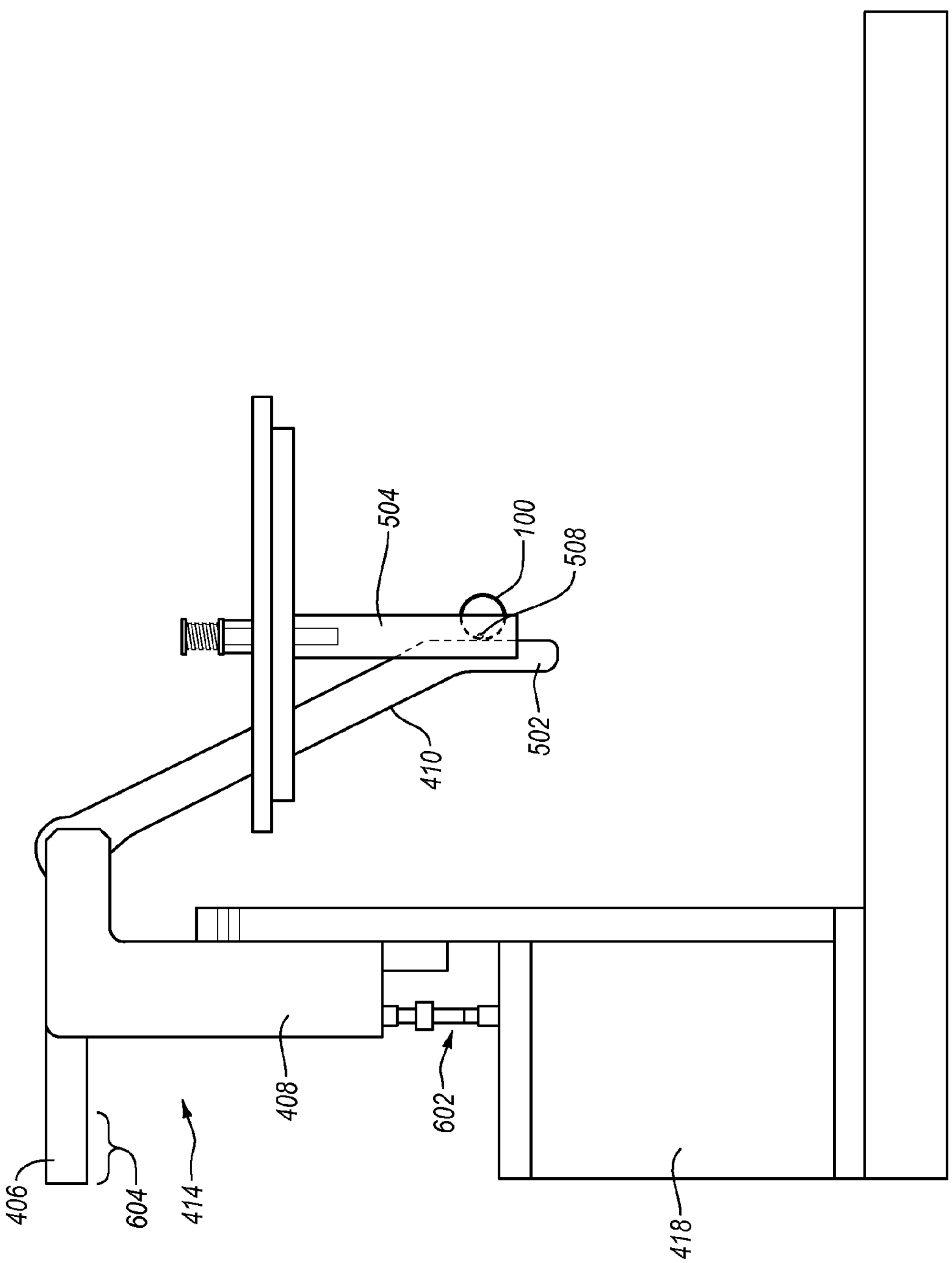


Fig. 6A

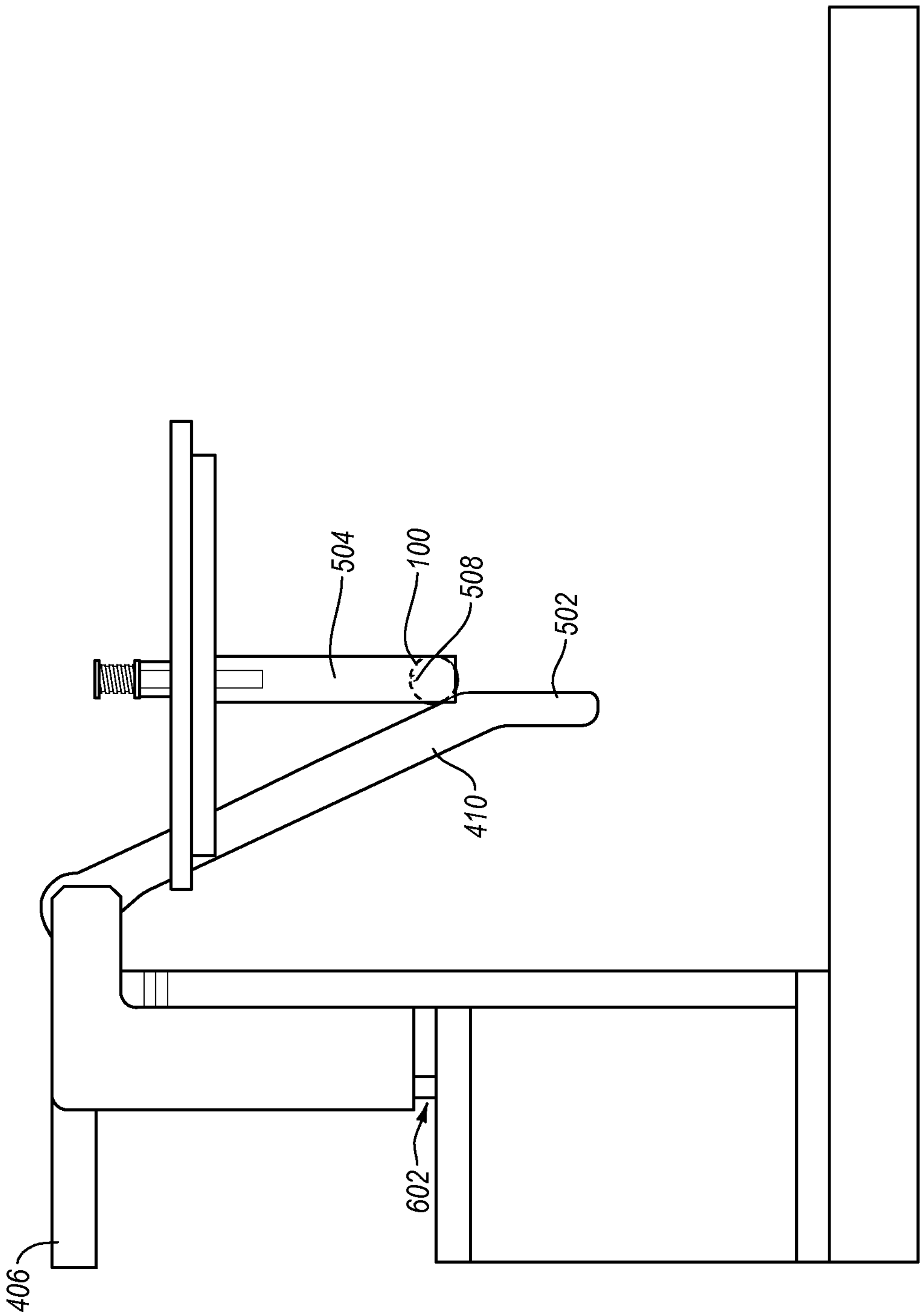


Fig. 6B

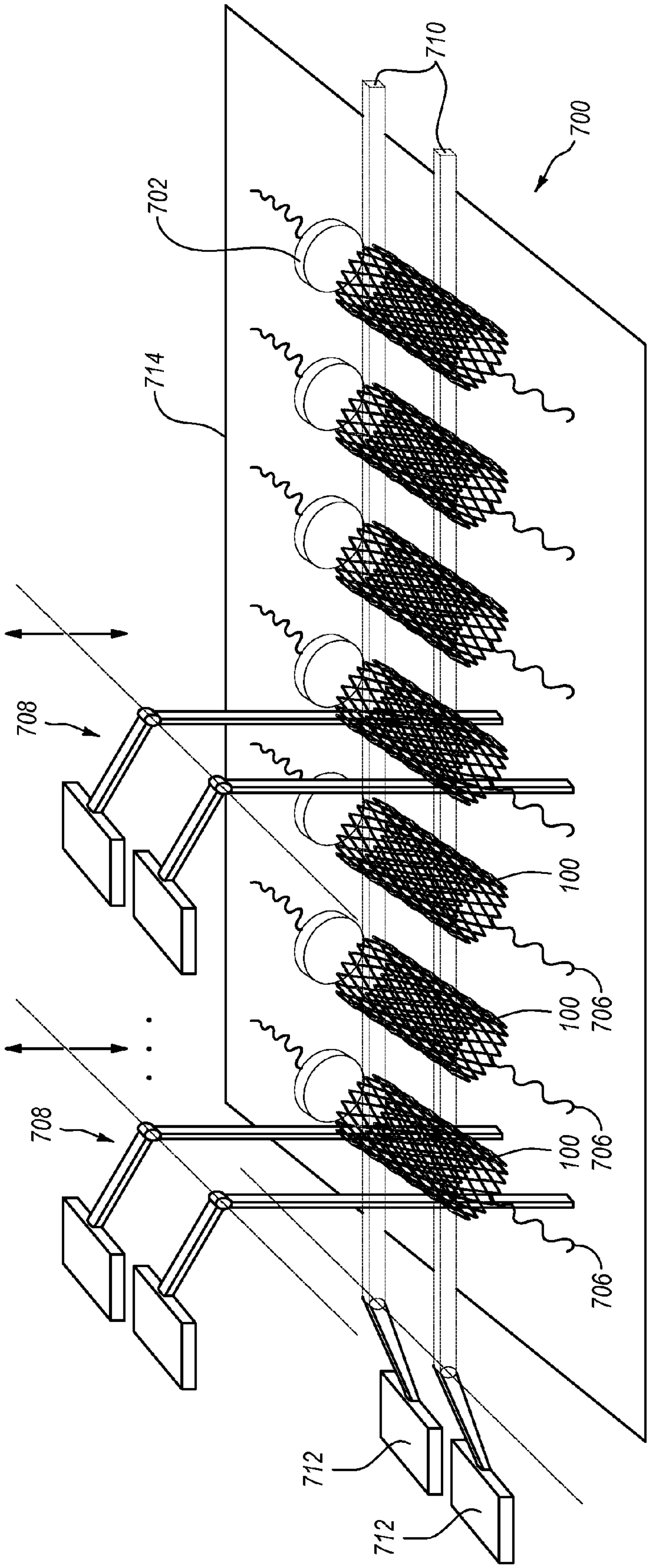


*Fig. 7*

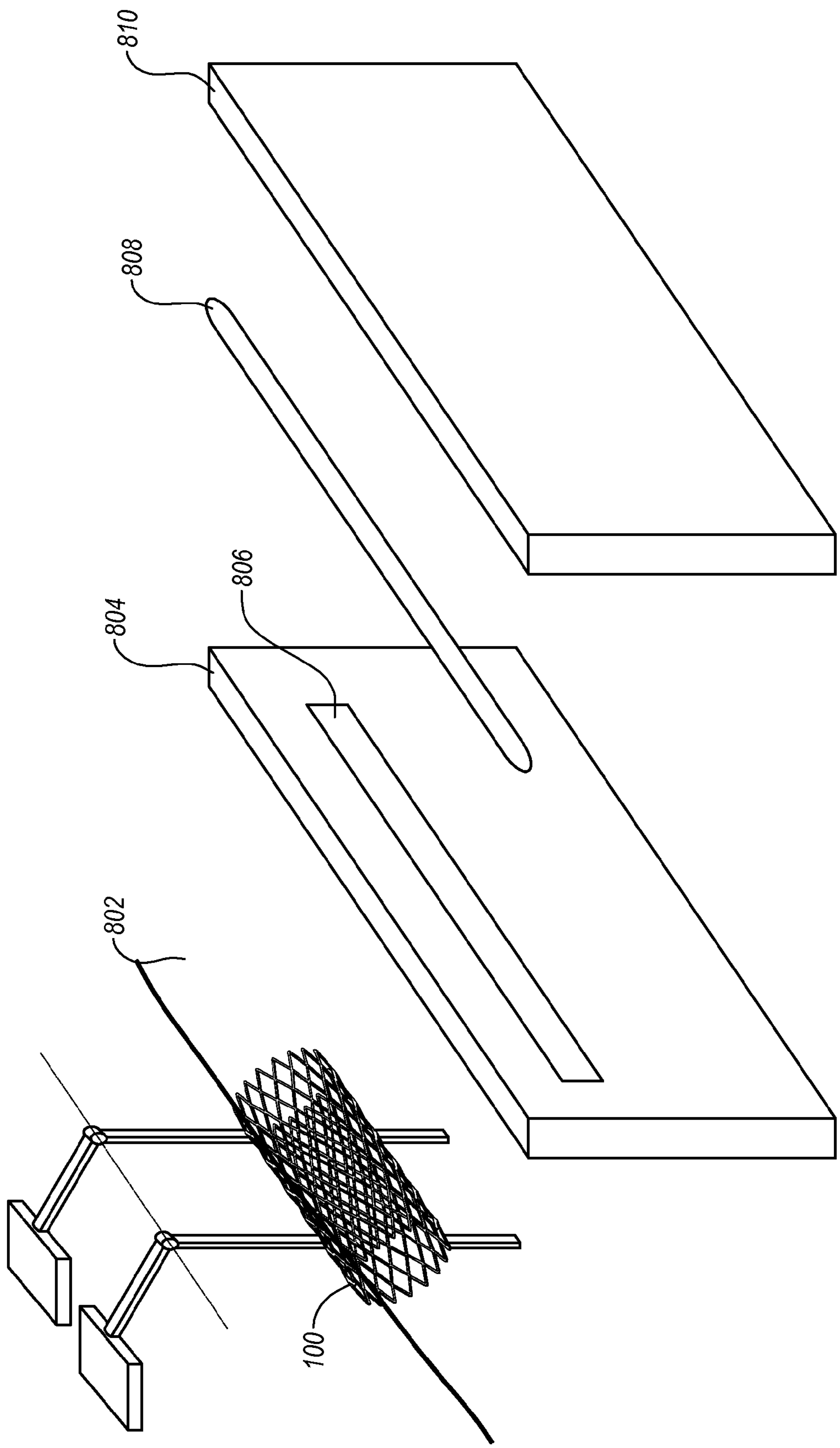


Fig. 8

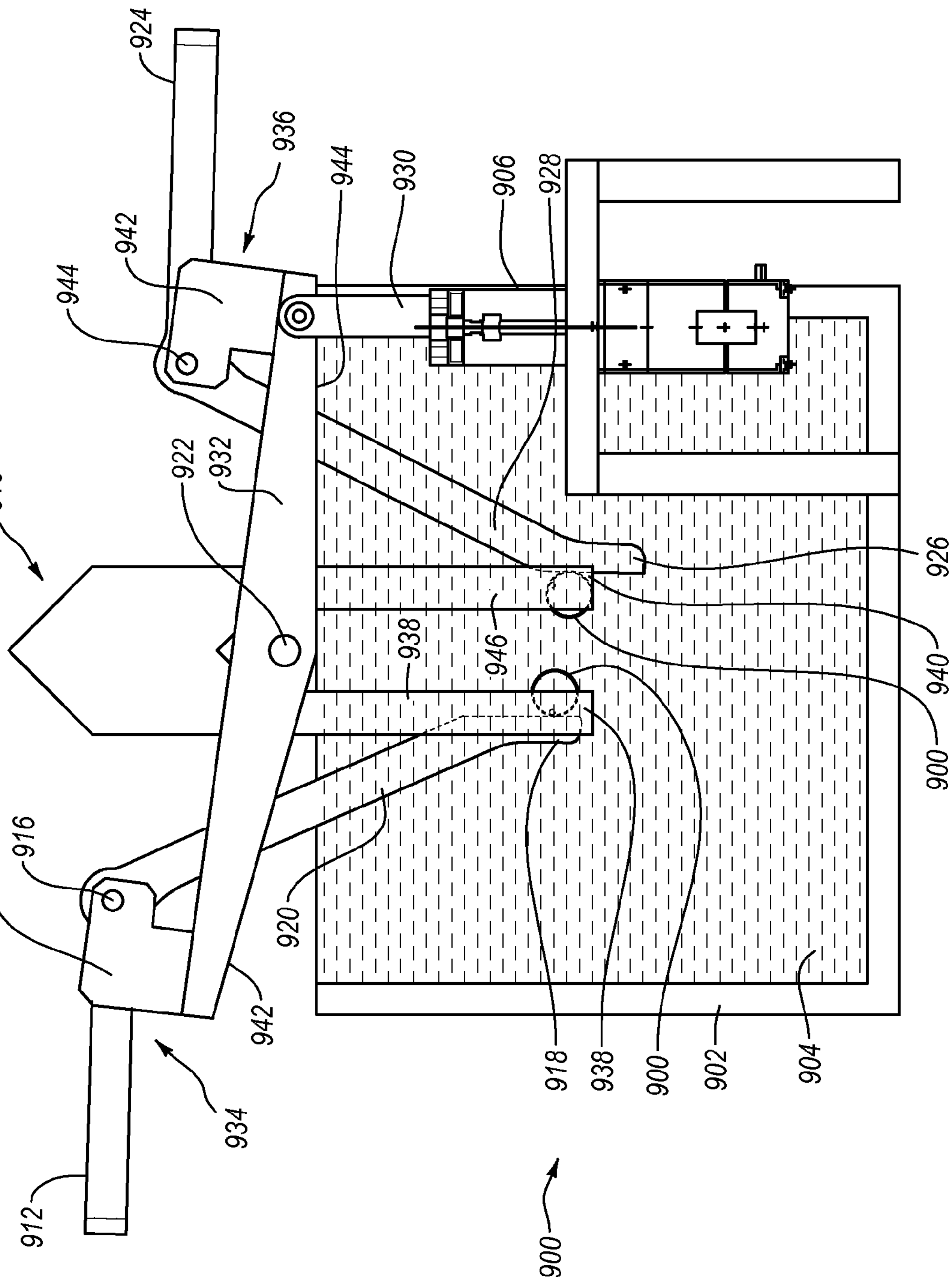
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*Fig. 9*

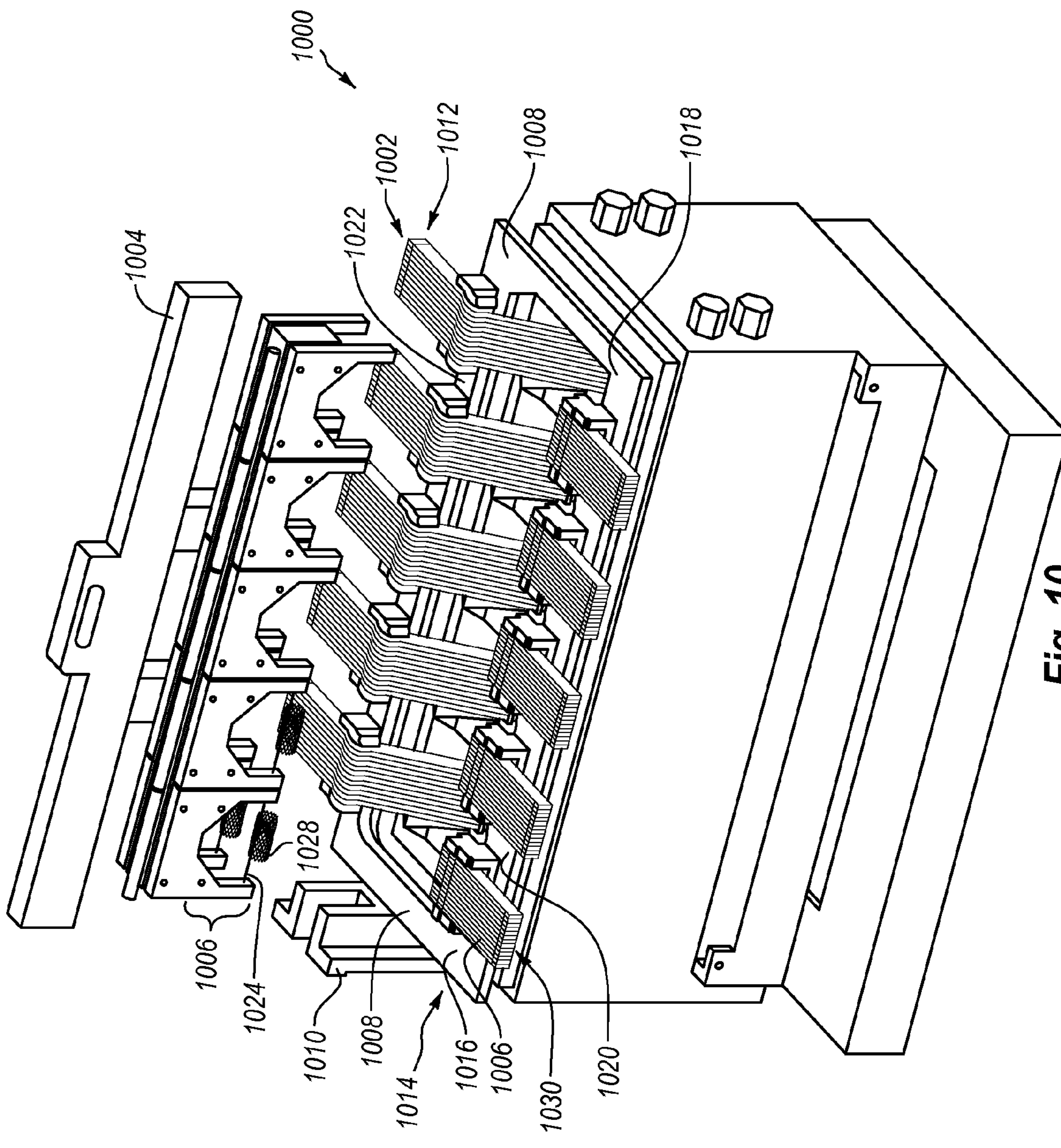
1000
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Fig. 10

# ELECTROPOLISHING FIXTURE WITH LEVER ARM

## BACKGROUND OF THE INVENTION

Medical devices are an important part of the health industry and are responsible for the health of many people. Many life-saving procedures can be performed today because of advances in medical device technology. Stents, for instance, are examples of medical devices that are used in a variety of medical procedures. When stents are used in the context of the vascular system, they can prevent, open, or counter act the flow of blood in situations where a patient's vasculature is weak or blocked. Stents are not limited, however, to the vasculature system and can be employed in many systems and circumstances.

The production of medical devices such as stents can be a complicated process. Producing the stent includes forming struts that are arranged to provide strength and flexibility to the stent. The struts can be formed, for example, by laser cutting.

Once the stent is formed, the stent needs to be polished. The stent is polished in order to remove the rough or sharp edges that may remain on the stent and to smooth the surface of the stent. As one can image, a stent with rough or sharp edges may have adverse effects if introduced into a patient's vasculature.

Electropolishing is an example of a method used to polish stents. Electropolishing is a common process that is usually performed by immersing the stents in an electrolytic bath. In conventional systems, however, maintaining a consistent surface finish can be difficult.

More specifically, electropolishing a stent often requires contact between the stent and an electrode. The contact points between the electrode and the stent surface, however, impedes electropolishing at the contact points. As a result, the stent may be polished at a different rate at or near the contact points compared to other areas of the stent. Ideally, a device being electropolished will remain immersed since it minimizes the risk of contamination to the stent surface. However, when manufacturing devices such as stents, it may be difficult to keep the stent immersed for the entire polishing process since there is also a need to rotate the stents throughout the electropolishing process. By rotating the stent, the contact area between the stent surface and the anode conductor is varied, which ensures that the entire stent surface will be polished. Existing methods of producing this rotation while the stent remains immersed are insufficient because the pressure required to clamp a stent on an anode and provide good electrical contact can be excessive and can result in damage to the stent structure when the stent is rotated.

## BRIEF SUMMARY OF THE INVENTION

Embodiments of the invention relate to an electropolishing system that includes electropolishing fixtures. Each fixture is configured to press the devices being electropolished against an anode, which may be conductive, to establish electrical contact and to reposition the devices during the electropolishing process. The electropolishing system may simultaneously electropolish multiple devices, which may or may not be of the same size and/or shape.

In one example, a system for electropolishing devices includes a first row of electropolishing fixtures and a second row of electropolishing fixtures. Each of the electropolishing fixtures in the first and second rows are configured to reposition at least one device being electropolished. The system also includes an actuator configured to move the first and second rows of electropolishing fixtures such that the electropolishing fixtures reposition the devices being electropolished.



Each electropolishing fixture may be associated with its own actuator. Alternatively, the rows of electropolishing fixtures may be connected to a rocking arm such that one actuator is capable of moving all of the electropolishing fixtures.

Each electropolishing fixture includes one or more lever arms that are mounted in a frame. The frame is provided with a pivot point and each of the lever arms may rotate independently about the pivot point. Each lever arm includes a distal end configured to contact the devices being electropolished. Each lever arm also includes a proximal end, which may be counterweighted. The counterweighted proximal end causes the lever arms to rotate about the pivot point such that the distal ends press the devices being electropolished against an anode, which typically passes through a lumen of the device and which may be conductive. Movement of the electropolishing fixtures results in rotation of the devices about the anodes.

In one example a method for electropolishing stents includes loading a plurality of stents on a row of posts. The row of posts includes pairs of posts and each pair of posts includes a removably connected anode. The stents are loaded on the anodes. Then, the stents are immersed in an electrolytic bath and electropolished. During the electropolishing process, the stents are repositioned by corresponding electropolishing fixtures. Finally, the row of posts is removed from the bath and the stents are unloaded from the anodes.

These and other advantages and features of the present invention will become more fully apparent from the following description and appended claims, or may be learned by the practice of the invention as set forth hereinafter.

## BRIEF DESCRIPTION OF THE DRAWINGS

To further clarify the above and other advantages and features of the present invention, a more particular description of the invention will be rendered by reference to specific embodiments thereof which are illustrated in the appended drawings. It is appreciated that these drawings depict only illustrated embodiments of the invention and are therefore not to be considered limiting of its scope. The invention will be described and explained with additional specificity and detail through the use of the accompanying drawings in which:

FIG. **1** illustrates a perspective view of an example medical device;

FIG. **2** illustrates a block diagram of an example system for electropolishing a medical device such as a stent;

FIG. **3** illustrates a perspective view of a pendulum assembly of an electropolishing fixture that includes lever arms;

FIG. **4** illustrates an example system effective to electropolish devices such as stents;

FIG. **5**A illustrates an another perspective view of the system shown in FIG. **4** including a view of the pendulum assembly;

FIG. **5**B illustrates an example of stent loaded on an anode between a pair of

FIG. **5**C illustrates an end view of the pendulum assembly engaging the sent such that the stent can be rotated about the anode;

FIGS. **6**A and **6**B illustrate movement of the electropolishing fixture and more particularly of the pendulum assembly effective to rotate a stent during an electropolishing process;

FIG. **7** illustrates an example of a system arranged to electropolish multiple stents simultaneously;

FIG. **8** illustrates an example of controlling an electrical field during an electropolishing process;

FIG. **9** illustrates another example of an electropolishing system that includes multiple electropolishing fixtures; and

FIG. **10** illustrates a perspective view of an electropolishing system configured to simultaneously electropolish multiple stents.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Embodiments of the invention relate to an electropolishing system that may include one or more electropolishing fixtures. Each electropolishing fixture may be configured for electropolishing devices including medical devices. Embodiments of the electropolishing fixtures include lever arms configured to place pressure against a device, electrode, or both during the electropolishing process. The lever arms may be electrically conductive and carry electrical current to the area of contact, or they may be insulated. In the latter case, the lever arms of the electropolishing fixture are operative to apply pressure between another conductive feature (e.g., an electrode or conductive mandrel) and the device. Embodiments of the invention are discussed in the context of a stent, which is an example of a medical device. Embodiments of the invention are applicable to the electropolishing of other devices as well.

When electropolishing a device such as a stent, the stent is placed over a mandrel, which may be conductive, and submerged in an electrolytic bath. The mandrel may be fixed against an electrode contact or may be configured as an electrode. Alternatively, the mandrel may be non-conductive or not configured to deliver electrical current to the stent.

In order to ensure adequate contact between the stent and the mandrel, the stent may be contacted by one or more lever arms that swing or rotate about a hinge component and that may be part of a pendulum assembly. In other words, the lever arms are arranged in a pendulum assembly.

The pendulum assembly can swing about the hinge, allowing the lever arms to come into contact with the stent regardless of the stent's exact radial or spatial location relative to the hinge. Furthermore, the pendulum assembly can also move in an upward and downward direction. The pendulum assembly may include counterbalances that are spaced a distance to the side of the hinges and that may be integrated into the lever arms. The counterbalances create a moment about the hinge that will cause the lever arms to rotate in a direction. More specifically, the lever arms of the pendulum assembly will tend to rotate into contact with the stent. In one embodiment, the counterbalances or another portion of the pendulum assembly may also act as electrical contacts so that the pendulum can be made to conduct electrical current from an electrical source into the stent.

When the pendulum assembly and in particular the lever arms are in contact with the stent and the pendulum assembly is then moved, the contact between the stent and the lever arms is sufficient to generate rotation of the stent about the electrode (or anode) on which the stent is loaded. The amount of pressure required to cause this rotation is minimal, and since the lever arms only contact one side of the stent, the risk of damaging the stent due to clamping force or rotation about the anode is also reduced. In effect, the wall of the stent is sandwiched between the electrode and the lever arms.

The pendulum assembly can also be scaled such that multiple stents and anodes may be integrated within a stent rack. Alternatively, multiple fixtures, each including a pendulum assembly, can be arranged to electropolish multiple stents. In one example, multiple stents can be accommodated on each anode. In this example, the stents can be placed on mandrels that are fixed to a frame of the stent rack. In addition, multiple pendulum assemblies may be used and placed in contact with the stents to enable the automated rotation of the stents. Each anode in the stent rack, for instance, may be associated with a particular pendulum assembly.

The placement of the cathode relative to the stent can also affect the electropolishing process. In one example, the stent frame may include a partition that can be positioned between the stent and the cathode. The partition assists in controlling a direction and flow of electrical current between the anode and the cathode. The cathode can be configured in many different configurations and shapes. For example, the cathode may include a conductive rod, mesh or screen that is positioned on an opposite side of the partition relative to the stent. The electrical current will be directed to pass through an opening or window in the partition in order to reach the cathode. Thus, the electrical field around the stent can be controlled as the current path reshapes to reach the cathode. The partition may include, for example, a narrow window or the like that approximates at least some dimensions of the stent and/or the cathode. For instance, a narrower window causes electrical current flowing from the stent to the cathode to focus in order to pass through the window and tends to cause the side of the stent facing the cathode to be preferentially electropolished. For instance, a shorter window (shorter than the stent length), centered on the stent tends to cause the ends of the stent to electropolish less than the central regions of the stent. These examples illustrate that the window in the partition can be configured to preferentially electropolish the stent. In addition, the location of the stent relative to the window can be changed during the electropolishing process such that, by way of example only, different portions of the stent can be preferentially electropolished at different times.

In another example, the cathode may be reconfigurable and adjustable. For example, the spacing of the cathode relative to the stent may be changed to affect the stent current flow. Spacing may be varied, by way of example only and not limitation, between about 0.38-inch and 0.75-inch. In addition to the spacing, the window of the cathode may be reconfigurable to change the current path and/or direction. The configuration of the window can be changed using sliding panels positioned between the stent and the cathode. By sliding the panels toward each other, the gap distance between the panels is reduced and less of the cathode is exposed. Alternatively, by separating the panels further apart, more of the cathode is exposed. These changes in distance and exposure result in an overall modification to the polishing characteristics of the stent, and allow for greater control of the polishing process.

Generally, at any given time during the electropolishing process, a side of the stent closest to the cathode will electropolish at a greater rate (e.g., mass removal rate) than the side of the stent the furthest away from the cathode and/or in contact with the lever arm. Thus, the operating characteristics of the electropolishing system can be controlled to more evenly electropolish stents. In some embodiments, the electropolishing current or voltage may be applied or turned on only when the stent is being rotated or repositioned. In some embodiments, short durations of current or voltage application without stent rotation may have insignificant effects. For instance, in many systems, the time for the stent rotation direction to reverse is not significant. In such embodiments, the electropolishing current or voltage may be applied, turned on or remain on when the stent is not being rotated or repositioned for short durations without significant effects. Furthermore, the stent may be rotated at a constant rate (rotational velocity) during electropolishing in some embodiments. Additionally, the stent may be rotated through multiple rotations during electropolishing. To make the electropolishing of the stent more even, the stent may be rotated in as near to whole rotations as practical. Additionally, the stent may be rotated both clockwise and counterclockwise and for the same number of rotations in each direction during electropolishing. Attention to and the careful selection/implementation of these operating conditions during stent electropolishing can cause the stent to be very uniformly electropolished. Testing has shown that stents electropolished under these conditions on fixtures as disclosed herein have more uniform dimensions than stents that are electropolished using a few (a practical number of) manual rotations on an interference fit anode (such as a tight-fit spiral mandrel) with cathodes that practically surround the stent.

Electrical current can be delivered to the stent in various ways. In one embodiment, the anode may also be the mandrel that holds the stent as previously discussed. In this example, the electrical current can be delivered into the stent directly through the mandrel, i.e. the anode. When the mandrel is also the anode, the lever arm or pendulum assembly may be an insulator and is not required to conduct electrical current. The pendulum assembly may be configured to impart rotational motion to the stent.

In an alternative embodiment, the mandrel may be insulated, which precludes the mandrel from also being an anode. In this example, the electrical current may be delivered into the stent through the pendulum, and through the lever arms of the pendulum assembly that are in contact with the stent. In either case, the anode may be connected to the power source using electrical connectors such as alligator clips or plugs.

The pendulum assembly can be configured in multiple variations. In one example, the pendulum assembly is configured to produce a horizontal load on the stent. The pendulum assembly may alternatively be configured to produce a vertical load on the stent.

A variety of mandrel or electrode configurations can be implemented. For example, the mandrel may be a sacrificial spiral mandrel. In the case of a sacrificial mandrel, the mandrel diameter may be slightly less than the inner diameter of the stent to allow the stent to rotate freely over its surface with minimal frictional loads. The mandrel may be made, for example, from a stainless steel or a nickel material, or some other inexpensive material. As a stent limiting stop, the mandrel may be overmolded with a polymeric bead or some other insulative material near one of its ends. This allows the stent to be placed over the mandrel and brought to a stop against the overmolded feature. Furthermore, the spiral mandrel may be sized to receive one or more friction fit spacers that can be brought near the end of a stent. The spacers may be insulative, such as formed from polymer or ceramic. Furthermore, the spacers may be configured to conform closely to the stent end. This may include a cup shape that conforms to and shields the stent ends.

As an alternative, a reusable spiral mandrel may be used. Such a mandrel would have a similar configuration to the sacrificial mandrel, but it would be constructed of more durable material. For example, the mandrel may be formed from Pt—Ir, Pt, Au, or any other conductive and durable material.

The pendulum assembly may include a counterbalanced lever arm that results in consistent pressure without the need for complex components that are susceptible to wear or deterioration under electropolishing conditions and thus, may require frequent adjustment and/or repair. In addition, embodiments reduce the need for tightly controlled alignment or spatial positioning between the lever arms and the stent/anode. This is useful because the acidic conditions tend to disrupt precise alignments due to wear and degradation of components. Additionally, the acid resistant fluorocarbon plastics that may be most easily formed or machined into components or used to coat components are difficult to machine or form with great dimensional precision and tend to deform over time due to stress relief, temperature changes or in response to applied forces.

Embodiments of the electropolishing fixtures and/or electropolishing methods disclosed herein can help reduce dimensional variability to a laser-cut stent, decrease stent handling damage and increase the throughput of the electropolishing process.

FIG. **1** illustrates a perspective view of an example medical device **100** and is referred to herein as a stent **100**. The stent **100** includes a body **110** that is generally tubular in shape, although other shapes and configurations are contemplated. The stent **100** has a first end **102** and a second end **104** that oppose each other. The body **110** includes struts **106** that are arranged to provide, by way of example only, strength and flexibility to the stent **100**.

The stent **100** may also have a thickness **114**, an inner diameter **116** and an outer diameter **118**. The difference between the inner diameter **116** and the outer diameter **118** defines the thickness **114** of the stent **100**. Embodiments of the invention can more evenly polish the stent **100** such that at least some dimensions, such as the thickness **114** of the body **110** or the dimensions of the struts **106** are more uniform. The stent **100** also includes a lumen **120**.

The stent **100** may be made of a material or alloy, such as Nitinol, stainless steel, cobalt-chromium, or the like, and has certain characteristics that facilitate operation of the stent. The stent **100** may be deformed (e.g., bent, compressed, expanded, or the like) by a force. For shape memory materials, when the force is removed, the stent **100** returns to its original shape. The elasticity and deformability of the stent **100** aid in the deployment of the stent **100** as well as in the operation of the stent **100**.

While manufacturing the stent **100**, the formation of the struts **106** or of the ends **102**, **104** can often results in edges **112** or other areas that are rough, sharp or unsmooth. In addition, the thickness **114** may not be uniform and the inner surface and/or outer surface of the stent **100** may be rough.

Electropolishing the stent **100** smoothes the edges **112** as well as the surfaces of the stent **100**. Polishing the stent **100** may prevent the stent **100** from causing problems once deployed. Electropolishing the stent **100** may also make the dimensions of the stent (thickness, strut dimensions, etc.) conform to the desired final dimensions and thus, for the stent **100** to attain its desired properties.

FIG. **2** illustrates a block diagram of an example system **200** for electropolishing the stent **100** or other device. The system **200** includes a container **208** that holds an electrolytic bath **206**. The system **200** electropolishes the stent **100** in the electrolytic bath **206** once the stent **100** is loaded on a fixture **220** (or on a mandrel) and immersed in the electrolytic bath **206**.

During the electropolishing process, the stent **100** is usually fully immersed in the electrolytic bath **206** along with an anode **202** and a cathode **204**. The anode **202** and the cathode **204** may be part of or separate from the fixture **220**. Prior to immersion in the electrolytic bath **206** or after immersion in the electrolytic bath **206**, the stent **100** is positioned such that the stent **100** comes into contact with the anode **202**. The contact may be initially established by gravity.

The fixture **220** may include lever arms that press the stent **100** against the anode **202** when the stent is immersed in the bath **206**. The fixture **220** may be configured such that the stent **100** can be removed from and immersed in the electrolytic bath **206**. For example, the stent **100** may be loaded on the anode **202** outside of the electrolytic bath **206** and then immersed for the electropolishing process.

Once the stent **100**, the anode **202** and the cathode **204** are immersed in the electrolytic bath **206**, a current **210** is then applied. The current **210** flows from the anode **202** to the cathode **204** through the stent **100** and the electrolytic bath **206**. In this manner, the stent **100** is electropolished.

More specifically, electropolishing uses electrochemical reactions to remove material from a surface of the stent **100**. Electropolishing tends to remove stent material that has increased electrical current densities. Portions of the stent's surface that are rough (bumps, shards, etc.) tend to have higher electrical current densities and are thus removed during the electropolishing process. The surface of the stent **100** is smoothed and polished by the removal of material from the stent's surface.

The fixture **220** included in the system **200** is configured to position the stent **100** and/or reposition the stent **100** within the electrolytic bath **206**. The fixture **220** can be controlled automatically and/or manually to position the stent **100** within the electrolytic bath **206** and reposition the stent **100** relative to the anode **202**. The fixture **220** may be immersed wholly or partially within the container **208** and/or the electrolytic bath **206**. Alternatively, the fixture **220** may be located outside of the container **208** as illustrated in FIG. **2**. The fixture **220** may be configured to be at least partially placed into and lifted out of the electrolytic bath **206** and/or the container **208**.

During the electropolishing process performed in the system **200**, the stent **100** is typically in contact with an electrode such as the anode **202** as previously stated. As a result, the anode **202** establishes contact points between the anode **202** and the surface of the stent **100**. The fixture **220** ensures that contact points exist between the anode **202** and an inner surface of the stent **100**. The anode **202** can be configured with one or more locations that are configured to contact the stent **100** (e.g., establish a friction contact) and the contact points between the anode **202** and the stent **100** can be on an internal surface of the stent **100** and/or an external surface of the stent **100**. Alternatively, the anode **202** may have a loose fit and the fixture **220** ensures that contact between the anode **202** and the stent **100** is established during the electropolishing process.

Current is supplied to the stent **100** through the anode **202**. The cathode **204** is electrically connected with the stent **100** via the electrolytic bath **206**. As a result, the current **210** flows to the cathode **204** through the electrolytic bath **206**. Current flow from the surface of the stent **100** is facilitated in this manner in order to remove material from the stent and thereby smooth the stent surface during the electropolishing process.

Contact points or more generally contact regions corresponding to the locations of contact between the stent **100** and the anode **202** have little or no current flow from the stent surface into the electrolytic bath **206**. As a result, the contact points or contact regions are not smoothed or polished in conventional systems or are not smoothed or polished at the same rate as other areas of the stent's surface.

The fixture **220** is configured to position the stent **100** to establish the contact regions between the stent **100** and the anode **202**. In addition, the fixture **220** is configured or can be operated such that the stent **100** may be repositioned over time. As a result of being repositioned, the contact regions between the stent **100** an the anode **202** change during the electropolishing process and the overall finish of the stent **100** is improved. When the contact regions are exposed after repositioning the stent **100**, current is then able to flow from the previous contact regions into the electrolytic bath **206** and to the cathode **204**. As a result, the surface of the stent is more evenly smoothed by automatically and/or manually repositioning the stent **100** during the electropolishing process.

In addition, positioning or repositioning the stent **100** can also result in a stent having better or more uniform dimensions. Repositioning the stent **100** can remove bumps or other portions of the stents' surface that may be rough, such as at contact regions, resulting in more even dimensions.

FIG. **2** thus illustrates the stent **100** positioned on the anode **202** or anode contact. The anode **202** is effective to deliver current to the stent **100** during the electropolishing process. In addition, the stent **100** benefits from being repositioned while immersed within the electrolytic bath **206**. Repositioning the stent **100** while the stent **100** is immersed prevents the stent **100** from being exposed to a more oxidizing environment and ensures more even erosion of the stent material during the electropolishing process.

FIG. **3** illustrates a perspective view of a pendulum assembly **326** of an electropolishing fixture **300** that includes one or more lever arms **310**. The fixture **300** is an example of the fixture **220**. In FIG. **3**, the stent **100** has been loaded on a mandrel **302**. For example, the mandrel **302** is inserted through the lumen **120** of the stent **100**. The mandrel **302** may be configured to operate as an anode. In this case, the lever arms **310** may be insulated and current is delivered through the mandrel **302** to the stent **100**. Alternatively, the mandrel **302** may be insulated and current may be delivered to the stent **100** through the lever arms **310**. At least one end of the mandrel **302** is removably connected to at least one of a frame or posts **328**. The posts **328** are configured to keep the mandrel **302** adequately tensioned during the electropolishing process. The posts **328** may be included in the electropolishing fixture **300** and may be configured to provide an electrical source connection to the mandrel **302**.

The fixture **300** is operable to move the stent **100** during the electropolishing process. The fixture **300** may be effective to establish electrical contact between the stent **100** and the anode **302**. With electrical contact established, the fixture **300** may then cause the stent **100** to be repositioned. In one example, the stent **100** is rotated about the anode **302**. Rotating the stent **100** or repositioning the stent **100** in this manner changes the contact points between the stent **100** and the anode **302**. Changing the contact points enables the old contact points to be more effectively electropolished.

The fixture **300** may include the pendulum assembly **326**. The pendulum assembly **326** includes one or more lever arms **310** that are mounted on an axis **318** (which may be part of a frame). The lever arms **310** include a counterweight **320**, a pivot point **316**, and a finger **312**. The pivot point **316** may be connected with the axis **318** (e.g., a rod) or other suitable structure that enables the lever arm **310** to at least rotate about the pivot point **316**. For example, lever arms **310** may be configured with an opening at the pivot points **316**. The axis **318** is inserted through the openings, thereby enabling the lever arms **310** to rotate about the axis **318**.

In the lever arms **310** (each pendulum assembly **326** may include one or more lever arms), the counterweight **320** may be acted on by gravity or by another force. The counterweight **320** has sufficient mass in one example to cause the lever arm **310** to rotate about the pivot point **316** and cause the fingers **312** to push against the stent **100** or, if appropriately positioned, against the mandrel **302**.

The fingers **312** press the stent **100** against the mandrel **302** or electrode. The finger **312** pushes with sufficient force to establish adequate electrical contact during the electropolishing process between the stent **100** and the anode **302**.

The finger **312** may have a textured surface **314**. The textured surface **314** may be configured to engage the stent **100** more effectively than a smooth surface. The textured surface **314** may have teeth, roughness, grooves, a spongy or soft surface, or the like. The textured surface **314** may also be smooth.

The counterweights **320** of the lever arms **310** cause the fingers **312** to move radially (in the direction of arrow **322**). The counterweights **320**, as previously stated, push the fingers **312** against the stent **100**. The fixture **300** is also configured to move the lever arms **310** vertically (or in another direction depending on the configuration of the fixture) in the direction of the arrow **324**. The fingers **312** may contact the stent in a tangential manner. Movement in the tangential direction while the fingers **312** are pressed against the stent **100** by the counterweights **320** causes the stent **100** to rotate about the anode **302**. As a result, the stent **100** is repositioned relative to the anode **302**.

FIG. **4** illustrates a system **400** effective to electropolish devices such as stents. FIG. **4** illustrates an electropolishing fixture **414**, which is an example of the fixture **300** or the fixture **220**, that cooperates with a container **402** (which may alternatively be part of the fixture **414**) to electropolish a device. The fixture **414** includes, in one embodiment, a frame **408** configured to hold a pendulum assembly **404**. The frame **408** is mounted on a base **418**.

The pendulum assembly **404** includes lever arms **406**. Each of the fingers **410** of the lever arms **404** extend into an interior of the container **402**, which may hold the electrolytic bath, a cathode, or the like. The frame **408** connects with the pendulum assembly **404** at a pivot point **416**. The counterweighted proximal ends of the lever arms cause the lever arms **406** to rotate about the pivot point **416**. The fixture **414** may also include a frame assembly **412**. The frame assembly may be configured to include a cathode and be immersed in an electrolytic bath held in the container **402**. The frame assembly **412** includes a top **420** in which contacts **422** are provided. Distal ends of the contacts **422** are configured to receive a mandrel or electrode on which a stent may be loaded. The posts **422** can be connected to an electrical source in order to deliver current to the mandrel.

FIG. **5**A further illustrates the system **400** with the container **402** removed. FIG. **5** illustrates that the fixture **414** may include posts **504**, which are connected with the contacts **422**. Distal ends of the posts **504** are configured with contacts **506**. An electrode **508**, on which the stent **100** is loaded, is strung between the contacts **506**. The posts **504** are generally insulated and an interior conductor is accessed at contacts **422** outside of the container **402**. When an anode is attached to the contacts **506**, an electrical source can be connected to the contacts **422** to deliver current to the anode and thus to the loaded stent.

FIG. **5**A further illustrates that the distal ends **502** of the fingers **410** may be pressed against the stent due to the counterweighted proximal ends of the lever arms **406**, thereby causing a portion of the inside surface of the stent **100** to press against the anode.

FIG. **5**B illustrates a view of the stent **100** loaded on the posts **504**. FIG. **5**B illustrates that movement of the distal ends **502**, when pressed against the stent **100** to establish electrical contact between the stent **100** and the anode **508**, result in rotation of the stent **100** about the anode **508**.

FIG. **5**C illustrates a side view of the fixture **414**. FIG. **5**C illustrates the distal ends **502** pressed against the stent **100** to establish electrical contact between the stent **100** and the anode **508**. Movement of the distal ends **502** rotates the stent **100** in the direction **520** in this example.

FIGS. **6**A and **6**B illustrate movement of the electropolishing fixture and more particularly of the pendulum assembly effective to rotate a stent during an electropolishing process. FIGS. **6**A and **6**B illustrate movement of the fixture during an electropolishing process. FIG. **6**A illustrates the fixture **414** in a first or extended or raised position relative to the posts or the anode or the stent or stent assembly. FIG. **6**B illustrates the fixture **414** in a second or retracted position or in a lowered position relative to the posts or the anode or the stent or stent assembly. More specifically, FIGS. **6**A and **6**B illustrate a lift **602**, which is an example of a translation mechanism adapted to move the fixture or the pendulum assembly and which may be motorized by a motor mounted in the base **418**, that is attached to the frame **408**. The lift **602** is operative to move the fixture **414** between a first position and a second position. The lift **602** can be controlled to repeatedly move the fixture between the first and second positions or anywhere inbetween.

As the lift **602** moves the fixture between the first and second positions, the fingers **502** press against a stent arranged, for example, as illustrated in FIG. **3**. The lever arms **406** are counterweighted on the proximal ends **604** such that the fingers **410** or distal ends **502** of the lever press against the stent. With movement of the fixture **414**, the pressure exerted by the distal ends **502** cause the stent to rotate relative to the anode, while maintaining continuous contact between the stent and the anode.

During the electropolishing process, the stents can thus be rotated by moving the fixture between the first and second positions. The movement of the fixture can be periodic, on a timed basis, or in another manner. The lift **602** may be powered by a motor, hydraulically, pneumatically, or the like and may be controlled by a controller or other computing device.

In FIG. **6**A, the lift **602** is extended and in FIG. **6**B, the lift **602** is retracted. Controlling the retraction and extension of the lift **602** results in corresponding movement of the fingers **502** up and down relative to the posts, anode, stent and/or stent assembly, which results in repositioning of the stent during the electropolishing process.

FIG. **7** illustrates an example of a system **700** for electropolishing multiple stents at the same time. In FIG. **7**, the stents **100** are loaded on a frame rack **714**, which includes a plurality of anodes **706** that extend from one side of the rack **714** to the other side of the rack **714**. Current can be supplied to the anodes **706** through the rack collectively or individually.

The stents **100** may be prevented from disengaging anodes **706** in one direction by a stop **702** to aid in handling the stent/anode assembly. The stops **702** may be an overmolded or interference fit portion adapted to cooperate with and position the stents **100** on the anodes **706**. When multiple stents are electropolished on a single anode **706**, spacers may be placed between adjacent stents, to prevent stent ends from engaging with each other and interfering with each other's electropolish processing or damaging each other. Such spacers may be a slight interference fit or loose on anodes **706**. The surface portions of stops **702** and spacers that face the stent ends may have various configurations, such as a flat surface or a surface that over-hangs a portion of the stent end (to limit or prevent stent end ring over-polishing) and or other surfaces/bevels to guide lever arms onto the stent. The cross-sections of stops and spacers may be circular to provide the least friction/wear with the lever arms that they may engage and to facilitate a cylindrically symmetrical electropolishing solution/electrolyte electrical field around the stent, which aides in the uniform electropolishing of the stent. The fixtures **708** are then placed relative to the stents **100** such that the stents **100** can be rotated during the electropolishing process. In one example, the rate of rotation for each stent can be individually controlled. As a result, different stent types can be simultaneously electropolished. In addition, current to each anode **706** can also be individually controlled, which has a corresponding impact on the electropolishing process of each stent **100** individually.

FIG. **7** also illustrates an alternative arrangement of lever arms **710** (shown in phantom for convenience). The lever arms **710** are arranged underneath the stents **100** in this example. As a result, a single fixture including the lever arms **710**, which each have a counterweight **712**, can be used to rotate each of the stents **100**. In this example, a single fixture can be used to rotate multiple stents. FIG. **7** thus illustrates that the lever arms can be oriented between the stents, or laterally with respect to a plane of the stents **100**. In each case, the lever arms can be configured such that gravity acts to press the lever arms against the stents.

In some embodiments, each of the lever arms in a fixture are independent and can move independently of other lever arms in the fixture. In one example, the outer most lever arms may be configured to touch the anode and deliver current rather than contact the stent for rotation of the stent. In this case, the distal ends of the current delivering lever arms may have a paddle or other configuration to more effectively deliver current.

FIG. **8** illustrates an example of a system for controlling an electrical field during an electropolishing process. FIG. **8** illustrates the stent **100** mounted on a mandrel or anode **802** in this example by passing the anode **802** through the lumen **120** of the stent **100**. A cathode **808** is also illustrated. During the electropolishing process, current passes from the anode **802** to the stent **100** by contact and from the stent **100** to the cathode via the electrolytic bath in which the stent **100**, the anode **802** and the cathode **808** may be immersed.

FIG. **8** illustrates shielding **804** and shielding **810**, which may be configured of PTFE. In this example, the shielding **804** has a window **806**. By controlling or setting the relative placements or locations of the stent **100**, anode **802**, shielding **804**, window **806** (and/or shape thereof), cathode **808** (and/or shape thereof), and/or shielding **810** (and/or shape thereof), an electric field generated during the electropolishing process can be controlled. Controlling the electric field (or current path) can be used to more effectively control the electropolishing process. The cathode **808** may be completely shielded except for the window **806** (encased within the shielding), or partially shielded as illustrated in FIG. **8**. Further, the cathode **808** may be a rod, a plate, a mesh plate or have another configuration that is larger than the window **806** and smaller than the shielding **804** and **810**.

FIG. **8** further illustrates that the shape, configuration, and or placement of the shielding **804**, **810** and/or of the cathode can thus be optimized for effective electropolishing. Like other embodiments disclosed herein, the cathode **808** may be a wire, a wire mesh, placed on one or more sides of the stent **100**, or the like.

The window **806** can be an integral part of the shielding **804**. Alternatively, the shielding **804** may be composed of movable panels. Two moveable panels (or a situation where one panel is fixed and the other panel is moveable) can be positioned in a manner to control the size and/or orientation of the window **806**. The panels may be placed in guides such that the panels can be slid towards each other. The panels may be held in place by friction between the panels and the guides. In addition, the size and/or location of the window **806** can be changed during the electropolishing process.

FIG. **9** illustrates an example of an electropolishing system **900** configured for electropolishing devices. FIG. **9** illustrates another example of an electropolishing system that includes multiple electropolishing fixtures. The electropolishing system **900** includes multiple fixtures, including the fixture **934** and the fixture **936**. The fixtures **934** and **936** are arranged on opposing sides of a center frame **910**. Posts **938** and **940**, which may be part of the center frame **910**, may extend into the bath **904** and are configured to hold stents. More specifically, each of the fixtures **934** and **936** may associate with a pair of posts between which an anode is attached. As previously stated, one or more stents may be loaded on each mandrel or anode that is connected to each pair of posts.

FIG. **9** also illustrates a cathode assembly **946**. The cathode assembly **946** can include a cathode of any appropriate shape (e.g., rod, plate, mesh plate) and/or shielding in one example. The cathode in the cathode assembly **946** may also be configured to be located on one or more sides of the stents **100**. For example, the cathode assembly **946** may be configured like the cathode **808** illustrated in FIG. **8**. The cathode **808** could be placed between the posts **938** and **940** as illustrated in FIG. **9**. The shielding **804** and/or **810** could also be included in the system cathode assembly **946**. With a cathode assembly **946** placed between the posts **938** and **940**, the cathode assembly **946** may include shielding with a window (such as the shielding **804**) can be provided for each fixture **934** and **936**. The shielding can be placed on either side of the cathode. As a result, the windows in the shielding on opposite sides of the cathode could face the stents loaded on the fixtures **934** and **936**. Because the system **900** can include multiple fixtures or multiple rows of fixtures, the cathode assembly **946** can be arranged to facilitate the electropolishing process.

For example, a cathode assembly can be provided for each stent or for opposing pairs of stents. Alternatively, the cathode assembly could be elongated to accommodate each row of fixtures. In this example, a single cathode could be used for all fixtures in the system **900**. In this example, the shielding can be configured with multiple windows (e.g., one for each stent or multiple windows for each stent).

The frame **914** of the fixture **934** is connected to the frame **942** of the fixture **936** by a rocking arm **932**. The rocking arm **932** is configured to rotate about an axis **922**. In this example, the rocking arm **932** rotates back and forth and is actuated by an actuator **906**. The actuator **906** connects with the rocking arm **932** by a push rod **930**. The push rod **930** is connected to both the actuator **906** and one end of the rocking arm **932**. The rocking arm may include sides **942** and **944** that are slanted. The angle of slant may be configured to correspond to the movement of the lift or actuator **906**. When fully retracted, in one example, the side **944** may rest on the container **902**, although this is not required. Rather, the sides **942** and **944** are configured or sloped relative to the container such that the rocking arm **932** can rock according to movement of the actuator **906**. If there is sufficient clearance between the container **902** and the rocking arm **932**, there may be no need to slope the sides **942** and **944**.

The actuator **906** may be electrically, pneumatically, or hydraulically powered or the like or any combination thereof. When operating, the actuator **906** moves the push rod **930** up and down. The connection between the push rod **930** and the rocking arm **932** may allow for relative movement or rotation. When the push rod **930** moves to an extended position, the fixture **936** is moved upwards by the rocking arm **932** and the fixture **932** is simultaneously moved downward by the rocking arm **932**.

As the actuator **906** moves the push rod **930** reciprocatively, the rocking arm **932** rocks or rotates back and forth around the axis **922** to translate the fixtures **932** and **936** between first and second positions (e.g., an up position and a down position).

The fixture **934** includes lever arms **912** that rotate about an axis **916** and that are mounted to the frame **914**. Because the lever arms **912** are weighted at the proximal ends, as previously described, the distal ends **918** of the fingers **920** press against the stents **100** loaded on the mandrel or anode, which extends between the posts **938** and between the posts **940** on the other side of the system in FIG. **9**. The movement of the fingers **920** thus rotate the stent relative to the anode or mandrel on which the stent is loaded. The fixture **936** includes lever arms **924** that rotate about an axis **948** such that the proximal weighted ends cause, by gravity in one example, the distal ends **926** of the fingers **928** to press against the stent loaded in the posts **940**.

The center frame **910** may be configured to anchor the rocking arm **932** to the container or housing **902**. The frame **910** may be configure such that the posts **938** and **940** can be immersed in and removed from the bath **904**. This enables the stents to be loaded as necessary in one example. The frame **910** may be connected with the container **902** during the electropolishing process by a latch, by weight or other suitable connection. In addition, the frame **910** may be configured such that a current can be delivered to the anodes strung, as appropriate, between the posts **938** or the posts **940**. More specifically, anodes are strung between the posts **940** for the fixture **936** and are strung between the posts **938** for the fixture **934**. In this manner, multiple stents can be electropolished simultaneously.

FIG. **10** illustrates a perspective view of an electropolishing system **1000** configured to simultaneously electropolish multiple stents. The system **1000** includes a plurality of fixtures **1002**, each of which may be one of the fixtures disclosed herein. The system **1000** is an extension of the system **900** shown in FIG. **9**. Where FIG. **9** included at least two fixtures, the system **1000** includes at least a row **1012** of fixtures and a row **1014** of fixtures. The row **1012** of fixtures are opposite the row **1014** of fixtures. As illustrated in FIG. **9**, a cathode assembly may be placed between rows of fixtures during the electropolishing process or placed in another location.

In the system **1000**, movement of the row **1012** and the row **1014** is controlled by the rocking arm **1008**. The rocking arm **1008** includes a first end **1016** and a second end **1018** that are connected by sides **1020** and **1022**. The side **1020** is connected to each frame of each fixture in the row **1014**. The side **1022** is connected to each frame of each fixture in the row **1012**. As the rocking arm **1008** rocks, the sides **1020** and **1022** move up and down, which motion is transferred to the rows of fixtures. Thus, the teeter-totter type movement of the rocking arm **1008** causes the fixtures in the rows **1012** and **1014** to rotate the stents mounted on the mandrels or stents that are attached to the rows of posts **1006**. By way of example, FIG. **10** illustrates an anode **1024** on which is loaded the stent **1028**. The stent **1028** is rotated by a corresponding fixture **1030**. Other pairs of posts in the row of posts **1006** are similarly configured with anodes. When the row **1006** of posts is lifted up, the anodes can be loaded/removed from the anodes. When loaded, the row **1006** of posts is then dropped into the bath and the frame **1004** may hold the rows **1006** of posts in place during the electropolishing process.

The center frame **1004** cooperates with a frame portion **1010** such that the row of posts **1006** can be inserted/withdrawn from an electrolytic bath. Once the stents are loaded, the center frame **1004** is lowered into the bath with the stents loaded on the anodes are electropolished. The system is then actuated such that the fixtures in the rows **1012** and **1014** reposition the stents loaded thereon during the electropolishing process.

The present invention may be embodied in other specific forms without departing from its spirit or essential characteristics. The described embodiments are to be considered in all respects only as illustrative and not restrictive. The scope of the invention is, therefore, indicated by the appended claims rather than by the foregoing description. All changes which come within the meaning and range of equivalency of the claims are to be embraced within their scope.

What is claimed is:

**1**. An electropolishing fixture for electropolishing a device, the fixture comprising:

a pendulum assembly including a lever arm, the lever arm having a proximal end and a distal end, the distal end including a finger configured to directly contact the device with a surface of the finger, the proximal end having a counterbalance, and the lever arm being pivotally movable about a point located between the distal end and the proximal end; and

a translation mechanism configured to selectively raise and lower the pendulum assembly relative to the device, wherein the finger of the lever arm moves in a tangential direction relative to the device to rotate the device during movement of the pendulum assembly.

**2**. The electropolishing fixture of claim **1**, further comprising a frame, wherein the pendulum assembly is connected to the frame at a pivot point, wherein the lever arms rotate about the pivot point.

**3**. The electropolishing fixture of claim **1**, wherein the proximal end includes a counterweight configured to cause the lever arm to rotate about a pivot point and press the distal end against the device.

**4**. The electropolishing fixture of claim **1**, further comprising an anode assembly configured to hold the device during the electropolishing process.

**5**. The electropolishing fixture of claim **4**, wherein the anode assembly includes an anode and a pair of posts, wherein the anode is removably connected with the pair of posts and wherein an electrical current is supplied to the anode via the pair of posts.

**6**. The electropolishing fixture of claim **5**, wherein the device is loaded on the anode by inserting the anode through a lumen of the device, wherein the device fits loosely on the anode.

**7**. The electropolishing fixture of claim **6**, wherein the lever arm presses the device against the anode to establish electrical contact between the anode and the device.

**8**. The electropolishing fixture of claim **1**, wherein the pendulum assembly includes a plurality of lever arms, wherein each lever arm is configured for movement independent of the other lever arms.

**9**. The electropolishing fixture of claim **8**, wherein at least one of the plurality of lever arms is configured to deliver current to the device for electropolishing.

**10**. The electropolishing fixture of claim **9**, wherein the lever arm configured to deliver current includes a pad on the distal end that is configured to contact a conductive anode passing through a lumen of the device.

**11**. An electropolishing fixture for electropolishing a device, the fixture comprising:

a pendulum assembly including a plurality of lever arms, each lever arm is configured for movement independent of the other lever arms, each lever arm having a proximal end and a distal end, the distal end of a plurality of the plurality of lever arms including a finger configured to contact the device, the proximal end having a counterbalance, and the lever arm being pivotally movable about a point located between the distal end and the proximal end, at least one of the plurality of lever arms is configured to deliver current to the device for electropolishing and includes a pad on the distal end that is configured to contact a conductive anode passing through a lumen of the device; and

a translation mechanism configured to move the pendulum assembly in at least one direction, wherein the finger of the lever arm rotates the device during movement of the pendulum assembly.

**12**. The electropolishing fixture of claim **11**, further comprising a frame, wherein the pendulum assembly is connected to the frame at a pivot point, wherein the plurality of lever arms rotates about the pivot point.

**13**. The electropolishing fixture of claim **12**, wherein the proximal end includes a counterweight configured to cause the plurality of lever arms to rotate about a pivot point and press the distal end against the device.

**14**. The electropolishing fixture of claim **13**, further comprising an anode assembly configured to hold the device during the electropolishing process.

**15**. The electropolishing fixture of claim **14**, wherein the anode assembly includes an anode and a pair of posts, wherein the anode is removably connected with the pair of posts and wherein an electrical current is supplied to the anode via the pair of posts.

**16**. The electropolishing fixture of claim **15**, wherein the device is loaded on the anode by inserting the anode through a lumen of the device, wherein the device fits loosely on the anode.

**17**. The electropolishing fixture of claim **16**, wherein the plurality of the plurality of lever arms press the device against the anode to establish electrical contact between the anode and the device.

**18**. The electropolishing fixture of claim **17**, further comprising a shielding and a cathode, wherein the shielding is oriented with respect to the cathode and an anode so as to control an electric field while electropolishing the device.

**19**. The electropolishing fixture of claim **18**, wherein the shielding can be reconfigured during the electropolishing to change the electric field.

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